By-Catch

Shrimp Trawl Bycatch in the Galveston Bay System

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Commercial harvesting of shrimp from the Galveston Bay system is an important economic asset to the State of Texas. Annual harvest from Galveston Bay averages 3.5 million pounds and approximately $6.5 million. However, shrimp harvesting also may impact finfish and other invertebrates that may be of commercial, recreational, or ecological value by generating "bycatch", the unwanted or non-targeted portion of a shrimp trawler's efforts. Since the bay supports extensive commercial and bait shrimp industries, an analysis of the bycatch from the shrimp fishery is extremely important to the Galveston Bay characterization program. Bycatch species are usually discarded after shrimp (*Penaeus* spp.) and edible or bait fishes are removed. Of particular interest are recreational species populations such as red drum (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*) which the State of Texas (Texas Parks & Wildlife Department) augments through stocking programs. Very little information is available regarding bycatch of either the bait shrimp fishery (which operates throughout the year) or the bay commercial fishery (which has two main seasons).

Historical information on bycatch in Galveston Bay is limited to several studies during the mid 1980s (Lamkin, 1984; Bessette, 1986) in which samples were collected from live-bait vessels. In the Bessette study, bycatch CPUE (catch per unit effort) averaged 35.3 kg/hr (± 35.8 kg/hr). Atlantic croaker, Gulf menhaden, and spot croaker were the dominant species (by number and biomass) recorded and bycatch averaged about 65% (range = 2-98% for individual tows) of the total catch by weight. Results from new sampling efforts are comparable with respect to variability in distribution and abundance of bycatch species. Historical data show that recreational species (southern flounder, red drum, and spotted seatrout) were captured very infrequently. New sampling efforts indicate similar results during 1992. Similar to data collected in the historical studies, recreational species were caught frequently.

The National Marine Fisheries Service (NMFS) Galveston Laboratory conducted a comprehensive investigation of shrimp trawl bycatch in Galveston Bay during the 1992 shrimp harvest. This investigation addressed the magnitude, composition, and seasonality of bycatch associated with shrimp trawling operations in Galveston Bay. The delineation of status and trends of fishery organisms in the estuary would be enhanced if the magnitude of bycatch could be estimated. Specific objectives for this study included: 1) a review of historical information on trawling bycatch in Galveston Bay; 2) completion of new sampling efforts in three major fishing areas in Galveston Bay, collecting data to calculate the magnitude of bycatch; and 3) an attempt to link bycatch data from new sampling efforts with data from independent fishery surveys of the Texas Parks & Wildlife Department for developing indices, which can be used to estimate bycatch intensity in future years.

Prior to initiating new sampling and data collection efforts, an industry advisory panel was assembled to act as a vehicle of communication between the fishing industry and principal investigators for the project. The industry review panel was composed of three members encompassing commercial and live-bait fishing, as well as shrimp processing and distribution (retail and wholesale) interests. The primary functions of panel members were to review sampling methodologies and data reports; recommendations of the advisory panel were considered without bias. Furthermore, panel members maintained a link with the fishing community and assisted in obtaining fishing vessels to participate in the study.

NMFS observers accompanied commercial and live bait shrimpers during trawling operations in Galveston Bay between March and November 1992. On sampling days, individual fishermen were randomly selected from a pool of over 25 vessels throughout three major fishing zones within Galveston Bay: Trinity Bay, upper & east Galveston Bay, and lower & west Galveston Bay. Shrimpers were instructed to fish normally, in areas of their preference. Fishermen were compensated for allowing observers to collect samples and other trawl information. Samples from each tow (standardized weight of 25 lbs. each) were collected, iced, and returned to the laboratory for processing and analysis. Over the March-November period, sampling trip intensity followed seasonal fishing effort patterns; thus, ensuring that data collected were representative of the shrimp fishery trends during 1992. In addition to collecting bycatch samples, observers recorded tow location, duration and speed, net length and mesh size, and environmental parameters (salinity, temperature, water conditions, etc.).

A total of 296 tow samples were collected from 20 different vessels. The majority of the samples were taken from the upper (171) and lower (91) bay fishing zones (Figure 1). Only 34 samples were collected in Trinity Bay, due to lack of fishing effort in that area. Low salinities (April-July) and poor shrimp catches (June-August) in Trinity Bay were the primary reasons for the decrease in fishing intensity. Approximately 1/3 to 1/2 of the samples were collected from vessels that fish primarily for live bait shrimp.

Overall, magnitude and composition of bycatch were extremely variable with respect to location and season. Approximately 125 bycatch species were captured during the year, with most of the diversity observed in the middle and upper bay areas during June-September. Atlantic croaker (*Micropogonias undulatus*), Gulf menhaden (*Brevoortia patronus*), sand seatrout (*Cynoscion arenarius*), cutlassfish (*Trichiurus lepturus*), bay anchovy (*Anchoa mitchilli*), hardhead catfish (*Arius felis*), spot croaker (*Leiostomus xanthurus*), brief squid (*Lolliguncula brevis*), and blue crabs (*Callinectes sapidus*) were generally the dominant bycatch species caught. Ranking of dominant species varies somewhat due to size differences among species captured (i.e., the dominant species caught in terms of numbers may not be the dominant species in terms of biomass). Similar to data collected in the historical studies, recreational species were caught infrequently.

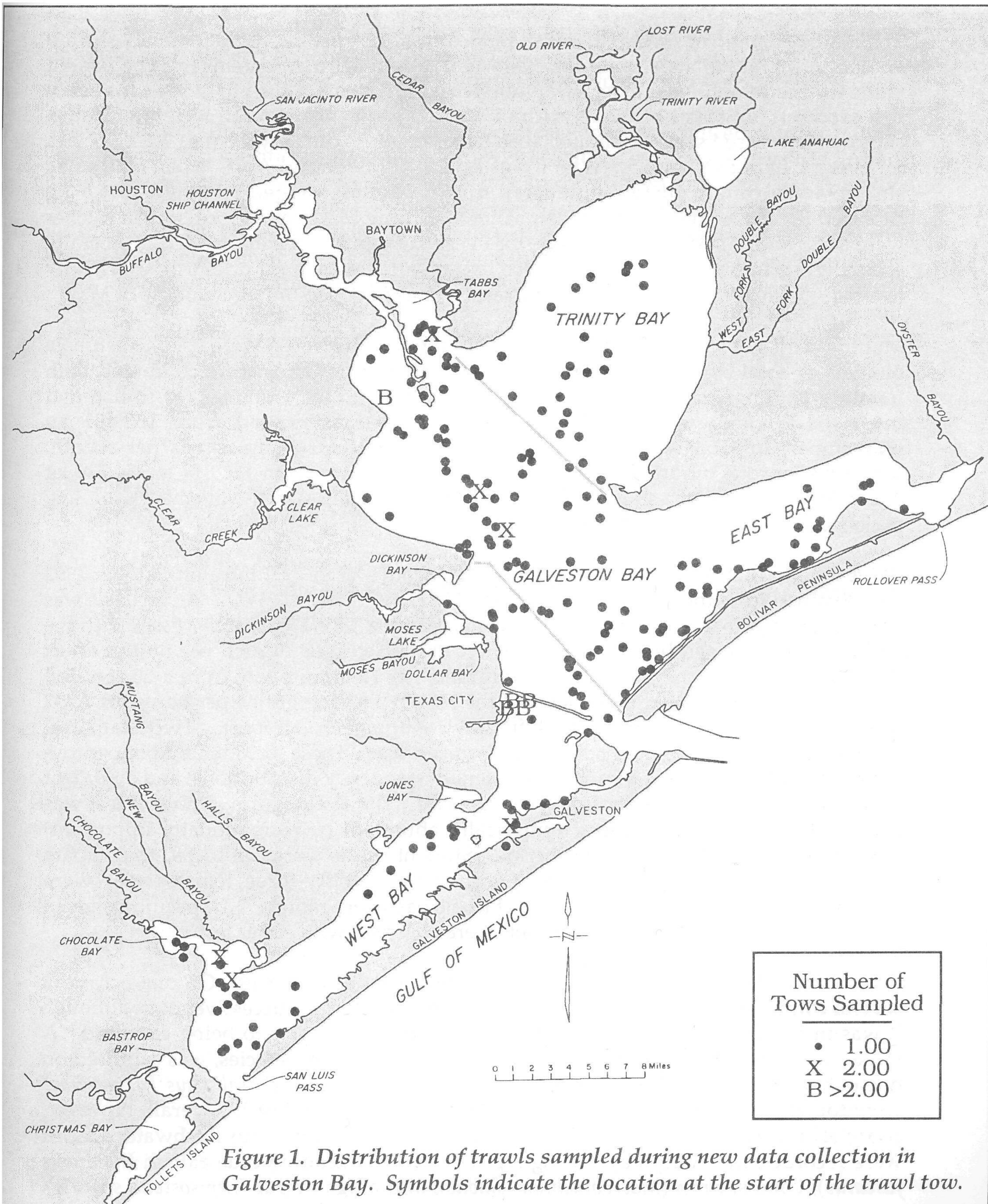

Figure 1. Distribution of trawls sampled during new data collection in Galveston Bay. Symbols indicate the location at the start of the trawl tow.

The numerical ratio of shrimp to finfish ranged from 10.7 fish captured for every shrimp landed in March, to 4.4 shrimp for every fish caught during September. The overall value for the March-November sampling period resulted 1.9 shrimp landed for every fish captured. In terms of biomass, the 1992 data shows that overall weight of finfish captured surpassed shrimp landings by a factor of approximately 2.6 (i.e., 2.6 kg of fish for every 1 kg of fish landed). With the exception of March and April (when only small shrimp were caught in few numbers), finfish biomass ranged from 1.0 to 4.9 kg captured for every kilogram of shrimp landed. During March and April, finfish catches were 32.78 and 17.33 kg, respectively, for every kilogram of shrimp landed. Generally speaking, shrimping effort during these two months is low and primarily exerted by live-bait shrimpers; the commercial bay season does not open until the middle of May.

Monthly ratios of shrimp to finfish (and shrimp to invertebrates) were used to estimate biomass of total bycatch for the Galveston Bay system. Ratios were compared with monthly landings data (collected by NMFS) to extrapolate estimates for finfish and invertebrate catch weights. The extrapolated values ranged from 105,481 kg (November) to 875,034 kg (July) of finfish captured in shrimp trawls per month. Estimates for total bycatch (invertebrates included) ranged from 121,817 to 954,776 kg per month. The overall estimate of total bycatch during the March-November sampling period is approximately 4,268,380 kg.

Galveston Bay fishery independent survey data from March 1992 through October 1992 was obtained from the Texas Parks and Wildlife Department (TPWD). An analysis was performed to compare the survey data collected by a TPWD research vessel with the bycatch data collected by NMFS from active shrimp vessels. Catch per unit of effort (CPUE) values from the TPWD data set (grams per 10 minute tow from a 20 ft trawl) were linearly extrapolated to the level of the NMFS data set (grams per hour from a 32 ft trawl, March-July; or from a 44 ft trawl, August to October). Two statistical comparisons were performed on the standardized data. These included a Kolmogorov-Smirnov test for statistical comparison of length frequency distributions, and a Student t-test on the CPUE values for individual species. The Kolmogorov-Smirnov test was performed on 17 species (most numerically abundant or recreationally important) caught during the March October period. Student t-tests were conducted to compare species-specific CPUE values during each month. Fifty-three total species were examined, although each was not present in the bay every month. No specific trends in statistical differences among the data sets were observed with either test.

Data of the 1992 samples include several noteworthy occurrences: On one occasion, several cormorants (*Phalacrocorax* spp.) were captured during successive tows, although it was impossible to determine whether they were dead prior to being captured. A large crevalle jack (*Caranx hippos*), a relatively fast-swimming species, was captured on one occasion. Some spotted seatrout and southern flounder (*Paralicthys lethostigma*) were found in oligohaline water (0%) in Trinity Bay during April. Overall, however, relatively few recreational species were caught by trawls. Numerous freshwater species were recorded in Trinity Bay during April and May including blue catfish (*Ictalurus furcatus*), Ohio shrimp (*Macrobrachium ohione*), and alligator gar (*Lepisosteus spatula*).

Small Spanish mackerel (*Scomberomorus maculatus*) were captured occasionally in the middle and upper portion of Galveston Bay. A spotfin butterfly fish (*Chaetodon ocellatus*) and a lane snapper (*Lutjanus synagris*) were caught in Lower Galveston Bay.

Data collected during this study only reflect those species captured during trawling operations. No specific tests were performed to examine survival of discards. Almost all of the fishermen who participated in this study utilized culling boxes (plywood enclosures with flow-through seawater) on their vessels. Trawl-caught items are placed in these culling boxes to minimize mortality of live-bait and facilitate ease of sorting bycatch. A number of factors are important in regulating survival of bycatch species (tow duration, magnitude of total catch, water temperature, injuries sustained in capture and/or culling, predation, etc.). Future investigations on bycatch should attempt to address survival of discards as well as the ecological role of bycatch species in species population dynamics and nutrient cycling.

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Recreational Fisheries Bycatch In Galveston Bay

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The Galveston Bay National Estuary Program is characterizing the status and trends in resource condition as a foundation for the Comprehensive Conservation and Management Plan for the Galveston Bay system. The purpose of this project was to examine the literature and existing data to determine the magnitude and composition of the recreational finfish and shellfish bycatch in the Galveston Bay system.

A preliminary estimate of the recreational bycatch of sport-boat fishermen was made using a combination of data obtained from the National Marine Fisheries Service's (NMFS) Marine Recreational Fishery Statistics Survey (MRFSS) and routine sport-boat harvest monitoring data provided by the Texas Parks and Wildlife Department (TPWD). Data from the MRFSS included landings of finfish, determined to species by NMFS contractors, and bycatch data (numbers and disposition by species) based on fishermen recall during intercept surveys. Data from TPWD included estimated annual landings of finfish by sport-boat fishermen as determined by TPWD fisheries professionals in intercept surveys.

Recreational sport-boat fishermen caught and released approximately two fish for every fish landed. Because of the limited nature of the data, estimates by species and year were not made. During the period of 1979-1985, the years of concurrent data collection by the NMFS and the TPWD, it was estimated that sport-boat fishermen caught and released between 1.2 and 3.5 million fish in the Galveston Bay system. Approximately 5% of the fishes reported released, were reported as being released dead. Available literature on hooking and handling mortality suggests that less than 15% of red drum released alive and up to 30% of spotted seatrout released alive die from injuries or stresses related to capture within seven days of being hooked, handled, and released.

TPWD professionals used sport-fishing techniques to capture spotted seatrout for tagging purposes. These "sport fishermen" had a lower total by-catch ratio than NMFS surveyed fishermen. TPWD professionals caught and released about one fish for every fish tagged. If it is assumed that fishermen fishing specifically for spotted seatrout would retain other desired species (e.g., red drum), the estimated by-catch by these specialty fishermen would be even less.

Because bycatch occurs during the fishing activity, typical methods, such as intercept surveys conducted at the completion of the fishing trip, do not provide verifiable data for estimating the composition and magnitude of the bycatch. Studies have shown that the marine fishermen, in general, can not identify accurately the fishes they catch, nor recall accurately specific events, such as the total numbers, by species, of fish caught. Therefore, studies relying on recall alone would produce data of extremely limited utility for a fisheries manager.

Additional studies suggested to further explore recreational bycatch include: *limiting by-catch recall studies to those species under management regulations*, using professionals (e.g., TPWD, NMFS, university or other biologists) to emulate sport-fishermen to determine composition and magnitude of bycatch, using volunteer fishermen to record catch information in logbooks, and assisting fisheries managers by conducting mortality studies of selected species.

No estimates for recreational shellfish bycatch were possible due to lack of information. It is believed that the magnitude of recreational shellfish bycatch is small relative to the commercial shellfish fishermen due to limited participation and stringent possession regulations.

Non-Fishing/Human Induced Mortality of Fisheries Resources

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Introduction

The purpose of this report was to evaluate and quantify the non-fishing human-induced mortality on fisheries resources in Galveston Bay. The specific objectives of the study were: (1) to collect and summarize existing information regarding authorized water intake structures in Galveston Bay; (2) to collect and summarize existing information regarding impacts to estuarine species from other non-fishing human activities, such as dredge and fill operations, seismic exploration, pipeline construction and removal, and other oil and gas exploration/production activities; (3) to quantify the magnitude of mortality to species by major taxa, size ranges, seasons, and areas within the Galveston Bay system; and (4) to present any implications of mortality patterns as they affect fisheries population dynamics in Galveston Bay.

Methods

The approach used by Jones and Neuse, Inc. (JN) consisted of a comprehensive review of literature and existing data on fish mortality caused by human activity other than fishing. This was accomplished by accessing information contained at the Galveston Bay Information Center, Texas A&M University - Galveston, other data bases (e.g., UTCAT, DIALOG, Scisearch, Biosis Previews, Oceanic Abstracts, Pollution Abstracts, Water Resources Abstracts), and on-going projects, as well as compiling published and non-published data from federal, state, and local entities. Data base searches focused on information specifically from Galveston Bay. These data bases were evaluated for information on a variety of causes of fish mortality including impingement and entrainment, dredge and fill operations, seismic exploration, pipeline construction and removal, and other oil and gas exploration/production activities. In addition, reports of fish kill investigations conducted by federal, state, and local agencies were reviewed. Data were quantified by causes, species, size ranges, magnitude, and spatial and temporal characteristics.

JN also sent questionnaires to permitted water rights users that withdrew water directly from segments within the study area, and withheld water for uses that would have the greatest probability of impinging or entraining estuarine organisms. The purpose of this questionnaire was to determine: (1) whether the permit was currently used; (2) the frequency and time of year of the diversion; (3) the quantity of water diverted; (4) the purpose of the diversion; (5) the intake rate and velocity; (6)

methods used to divert fish from the intake; and (7) whether the user had conducted any impingement and entrainment studies at their facility.
JN contacted Houston Lighting and Power (HL&P) to obtain all impingement and entrainment studies conducted at HL&P generating stations on Galveston Bay to determine the most frequently impinged or entrained species. The length, weight, and peak impingement periods for the most frequently impinged and commercially/recreationally important species were also identified. Other information obtained included injury rates, percent survival after impingement and entrainment, including the delayed effects of impingement and entrainment, and the effects of elevated temperatures in discharge canal waters for species of concern. Data was available for the following HL&P generating stations: P.H. Robinson (Landry, 1971 and 1977; Chase, 1977; McAden, 1977; Chase, 1978; and Greene et al., 1980a), Webster (Greene et al., 1980b), Sam Bertron (Greene et al., 1979), Deepwater (Greene, 1980), and Cedar Bayou (Jobe et al., 1980; and Southwest Research Institute, unpublished data).

Several agencies were contacted to obtain fish kill records. These agencies included the U.S. Environmental Protection Agency (EPA)-Region VI, the Texas Parks and Wildlife Department (TPWD), the Texas Water Commission (TWC) and its predecessor agency the Texas Department of Water Resources (TDWR), the Harris County Pollution Control Department (HCPCD), and the Galveston County Health District. JN requested records only from the TPWD or the TWC because they had the most complete and comprehensive data bases. In addition, all the other agencies reported fish kills to the TPWD or the TWC. However, several records were obtained from the Harris County Pollution Control Department. Reports used during the development of this study were limited to those containing numbers of fish killed and for which incidents occurred in either estuarine waters or tidally influenced waterways that were part of the Galveston Bay system.

Results

Cooling Water Operations — There was a great deal of information available regarding the effect of cooling water operations (e.g., impingement, entrainment, and elevated temperatures) on finfish and shellfish in Galveston Bay. By far, the majority of information came from studies conducted at the five HL&P generating stations located within the Galveston Bay area. Those facilities that had the greatest pumping rates and the highest intake velocities impinged and entrained the most organisms. A review of TWC permitted water rights users withdrawing water from Galveston Bay revealed that only one other facility besides the HL&P generating stations that could have a major impact on finfish and shellfish in the bay, a chemical plant in Texas City. However, no impingement and entrainment studies have been conducted at this facility.

The species most frequently affected by cooling water operations coincided with those that are probably most abundant in the bays. These species included white shrimp (*Penaeus setiferous*), brown shrimp (*Penaeus aztecus*), blue crab (*Callinectes sapidus*), Gulf menhaden (*Brevoortia patronus*), bay anchovy (*Anchoa mitchilli*), sand seatrout (*Cynoscion arenarius*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). Species less frequently impinged at all stations but still in large numbers included sea catfish (*Arius felis*), striped mullet (*Mugil cephalus*), Atlantic cutlassfish (*Trichiurus lepturus*), and least puffer (*Sphoeroides parvus*). Commercially and recreationally important species such as spotted seatrout (*Cynoscion nebulosus*), black drum (*Pogonias chromis*), red drum (*Sciaenops ocellata*), and southern flounder (*Paralichthys lethostigma*) were infrequently impinged and only in small numbers.

Organisms impinged or entrained were generally post larval crustaceans and juvenile fishes that could not swim faster than the intake velocities at the generating stations. Larval fishes and fish eggs were also entrained at these facilities. The most abundant larval fishes included naked gobies (*Gobiosoma bosci*), Gulf menhaden, bay anchovy, and comb-tooth blennies (family Blenniidae). The sizes most frequently impinged varied by station. The numbers of organisms impinged usually coincided with the life history of the organism.

Calculated overall probabilities of survival which included the immediate and delayed effects of impingement and entrainment and excluding the effects of elevated temperatures in the discharge canal were calculated for the HL&P Robinson station. Crustaceans (brown shrimp and blue crab) had overall probabilities of survival greater than 0.70 (greater than 0.45 for white shrimp) at Units 1 and 2. Overall probabilities of survival were lower at Units 3 and 4 (i.e., greater than 0.30 for white and brown shrimp and greater than 0.50 for blue crab). Overall probabilities of survival for fish were much lower than for crustaceans. Most fish had survival probabilities less than 0.10; however, spot had survival probabilities of 0.25 at Units 1 and 2 and 0.04 at Units 3 and 4. Higher injury rates and lower probabilities of survival at Units 3 and 4 versus those at Units 1 and 2 were related to greater pumping rates at Units 3 and 4.

The effects of impingement, passage through a fish pump, and long-term (i.e., 96-hr) survival were evaluated at the Cedar Bayou station. Survival rates immediately after impingement at the Cedar Bayou station were much greater than those reported at the Robinson station. Crustaceans (i.e., white shrimp, brown shrimp, and blue crab) had the highest immediate survival rates (> 95%). Most of the abundant fishes had survival rates greater than 70% with many, such as Gulf menhaden, spot, and southern flounder, greater than 90%. The most sensitive species was the least puffer with an immediate survival rate of 44%.

Survival rates immediately after impingement and passage through the fish pump were generally greater than 70% with for all species, with crustaceans (i.e., white shrimp, brown shrimp, and blue crab) among the highest (>84%). The most sensitive species were red drum (0%) and black drum (50%), but these results were suspect because the sample sizes were very small. Of the six species tested for long-term effects of impingement and passage through the fish pump, sand seatrout was the most sensitive with 13% survival. The remaining species tested (i.e., spot, Atlantic croaker, blue crab, white shrimp, and brown shrimp) had survival rates greater than 50%. Again, crustaceans were hardier than fishes.

Only six species were used in the heat-shock studies. No sand seatrout survived. Spot, white shrimp, and brown shrimp survival rates ranged between 19% and 27%. Atlantic croaker survival rates were 40%, while blue crab was the hardiest species tested with a 66% survival rate. Overall, survival rates for all species decreased from impingement to passage through the fish pump to placement in the discharge canal.

The effects of elevated temperatures were observed at 30°C for Gulf menhaden. Atlantic croaker were repelled from the Robinson discharge canal at 32°C. Bay anchovy, sea catfish, sand seatrout, and spot avoided temperatures greater than 35°C. Decreased survival for larval blennies was observed at the Robinson station when water temperatures reached 36.7°C with no individuals collected in the discharge canal when temperatures exceeded 38.4°C. At the Cedar Bayou station, blue crab survival decreased when discharge canal water temperatures exceeded 33.3°C with no survival when temperatures were greater than 36°C. No brown shrimp or white shrimp survived when discharge canal water temperatures were greater than 33.3°C at Cedar Bayou. At the Robinson station, fish egg survival ranged from 11.3% to 54.3% when discharge canal temperatures ranged from 38.4°C to 38.9°C. However, no fish eggs were found alive in cooling towers when temperatures ranged from 32.2°C to 34.7°C, indicating fish eggs were more sensitive to physical impacts from bouncing and splashing in the towers.

There were some beneficial effects noted from the discharge of heated effluent. During the late winter and early spring, rapid growth of young-of-the-year spot was observed in the Robinson canal. Also, large numbers of fish were found congregated in the canal and near the outfall during the winter months.

A comparison was made between the projected weight of sport and commercial species impinged at HL&P plants, except the Cedar Bayou station, between 1979 and 1980 and commercial and sport landings reported by TPWD for fiscal years 1979 to 1981. These years were selected because data were available for all HL&P generating stations only during this time period. The weight of brown and white shrimp impinged was generally less than 3.7%, and the weight of blue crabs impinged was less than 7.6% of the commercial landings. The weights of red drum, sand seatrout, and spotted seatrout impinged were all less than 2.1% of the sport-boat landings. The weights of black drum (<0.1%), southern flounder (<5.1%), and Atlantic croaker (<7.4%) impinged were all less than 7.4% of the total commercial and sport-boat landings. Based on these results, JN concluded that with respect to the 4 of 5 HL&P stations for which data were available, more species of interest were landed (by weight) either commercially or recreationally than the weight of these species impinged on HL&P intake screens.

During 1978 and 1979, over 32 million organisms weighing more than 234,000 kg were projected to be impinged per year at four of five HL&P stations on Galveston Bay. However, results of survival studies demonstrated that not all impinged organisms would die. Survival rates varied by facility, and crustaceans generally had higher survival rates than finfish. Survival rates decreased when impinged/entrained organisms were exposed to elevated temperatures. Fortunately, organisms would only be exposed to temperatures exceeding thermal tolerances between May and August, the time when fewer numbers of organisms were impinged.

Fish Kills — The fish kill reports used in this study (20 years of TWC/TDWR records, and 12 years of TPWD records) were limited to those that contained the number of fish killed. Each report documented a single incident resulting in fish mortality. A total of 321 reports that documented fish kills in the Galveston Bay system were identified. One hundred and one (101) of these reports were determined by JN to be either uninfluenced by human activity, outside of the study area, or did not include mortality data.

Sources of fish kills were grouped into three broad categories: point sources, nonpoint sources, and unknown sources. Point sources originated from localized areas for which the circumstances resulting in the release of a causal agent could be identified. These included wastewater outfalls, accidental spills, and seismic detonations. Nonpoint sources included regional areas for which a single controllable point could not be identified. Pollution emanating from these sources generally resulted from stormwater runoff from agricultural land, urban areas, or landfills. Nonpoint source events were included as a category separate from point sources since there is a certain amount of control potential associated with them and because they represented a large fraction of the fish kill incidents reported for the Galveston Bay area. A third category, unknown sources, was established for those incidents that were not attributable to either point or nonpoint sources.

An estimated 175.2 million finfish and shellfish were killed in the remaining 220 fish kills. The causes of 121 fish kills (i.e., 89% of reports evaluated) involving 156 million finfish and shellfish were unknown. The remainder of incidents reported and fish killed were attributed to point sources (approximately 2.4 million fish killed in 56 incidents) and nonpoint sources (16.3 million fish killed in 43 incidents). The causes of the majority of fish kills attributed to point sources were unknown spills at electric power generation facilities, sewage treatment plant by-passes, pipeline leaks and unknown spills at chemical plants, ocean dumping, and seismic detonations. No impingement- or entrainment-related fish kills were reported to state agencies. With respect to nonpoint source events, 93% of the mortality and 81% of the incidents were attributed to low dissolved oxygen from undefined runoff events.

Due to the lack of data, no trends were detected regarding the species killed or their length-frequency. However, Gulf menhaden was the species most often affected in nonpoint source related fish kills. Essentially, all of the fish mortality attributed to point sources occurred from May to October, with peaks in May and September. Nonpoint source related fish kills most often occurred from June through September with a peak in August. Fish kills most often occurred in tributaries to Clear Lake, East Bay, and West Bay, San Jacinto Bay, Dickinson Bayou, West Bay, and Clear Lake.

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